

## LIGHTNING PROTECTION OF ALTERNATIVE-CURRENT ELECTRICITY METERS

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**Summary:** Article presented the basic information about the lightning risk to alternative-current electricity meters, which are connected directly or indirectly to power system. It was proved, that on electricity meter, in the case of direct connection, can affect some part of lightning current and all types of overvoltages from low-voltage power system. In order to attain the estimation of lightning risk in indirect connection, overvoltages transfer through instrumental transformer to secondary sides were analysed. In recapitulation the protection against surge current and voltages was considered.

**Keywords:** Lightning, overvoltages, current and voltage transformers, alternative-current electricity meter, lightning protection.

### 1. Introduction

Failure-free working of electronic, multifunctional alternative-currents electricity meters was possible to achieve limiting to required levels the current and voltage surges in electric power systems. Selection and disposition of surge protective devices SPD required the information about the surge risk in power system and the resistibility of ac electricity meters to voltage and current surges.

### 2. Surge resistibility of electricity meters

One of the basic requirements of ac electricity meter is fulfils the appropriate dielectric properties in cases when different impulse disturbances appeared in power systems. For presentation of surge risk, the meters were tested [12] by surge voltage with peak value 6000 V and waveshape 1,2/50  $\mu$ s. The range of surge resistibility investigations were presented in Tab.1.

### 3. Surge exposure of electricity meters

Electricity meters can be connected:

- directly to low-voltage power system,
- half directly by current measuring transformers to voltage power system ,
- indirectly by current and voltage measuring transformers to high or medium voltage power

systems.

In dependence from arrangement of connections, in power systems on all types electricity meters can affect some part of lightning current and different types of overvoltages

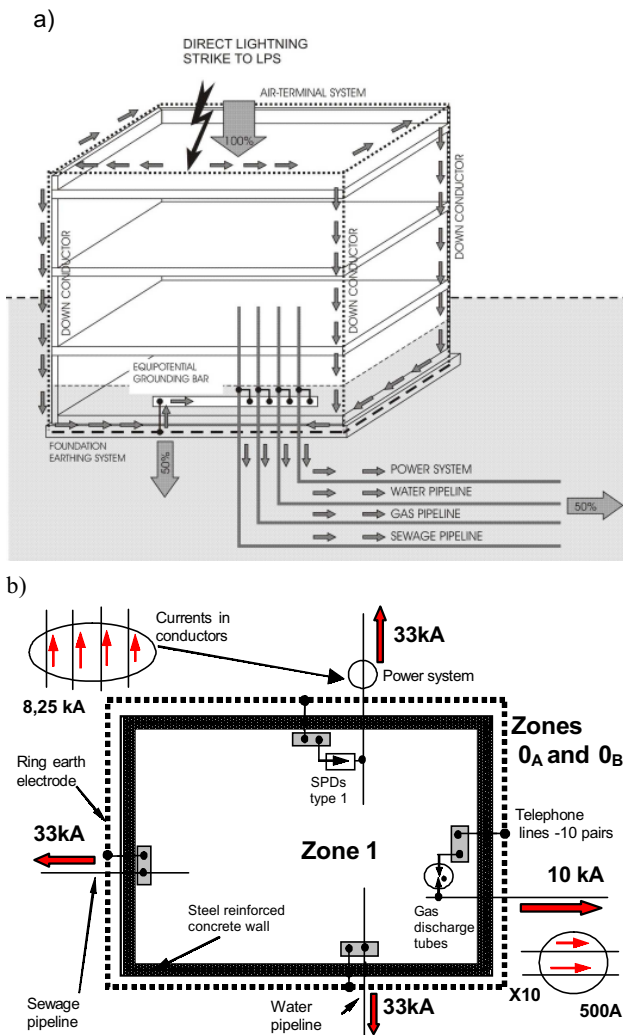
**Table 1.** Break-down strength tests for ac electricity meters

Tests	Ranges of tests	Remarks
Tests for circuit's insulation and insulation between circuits	Tests for individual circuits, which are insulated from other circuits	Terminals of circuits which are not tested connected to the earth
	Common tests for currents and voltage circuits.	When these circuits are connected together
	Tests for current circuits – impulse voltage between every terminal and earth.	
	Tests for voltage circuits – impulse voltage between every terminal and earth.	Voltage and current circuits are separated and each has the separate insulation
Tests for auxiliary circuits – the same tests as voltage circuits		
Tests for insulation between circuits and ground	All terminals in electric meter are connected. Impulse voltage between all terminals and earth.	Terminals of auxiliary circuits were connected together terminals of others circuits

### 3.1. Surge exposure in low-voltage power systems up to 1000 V

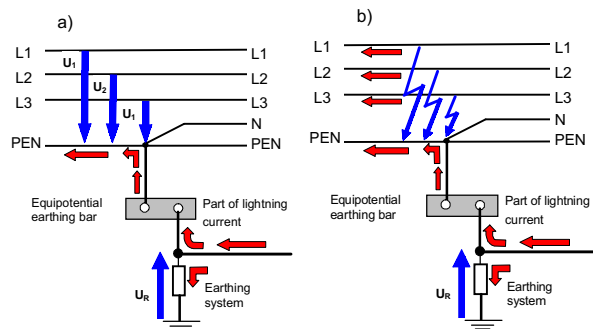
In building with lightning protection system LPS electric low-voltage power system and electricity meters connected directly to this system can be affected by some part of lightning current. Such risk appeared during direct lightning stroke into the air-terminal system of LPS.

In this case, according the recommendations in standards about lightning protection of structure [6, 7, 8] and requirements for SPD [5], 50% of lightning current is discharged through the earthing system of structure and odd part is distributed in the connected conductive systems (power system, metal piping, etc. - according to Fig.1.).



**Fig. 1.** Lightning current distribution during direct stroke to LPS, a) general view, b) current distribution in conductive installations

In all cases the electricity meter connected at the entrance directly to power system will be in danger caused by potential difference between conductors and earthing system (PEN conductor). Voltages increased up to insulation breakdown (Fig. 2.), with high probability breakdown in electricity meter. Next lightning current flows in phase conductors.



**Fig. 2.** Lightning current distribution in low-voltage power system: a) current only in PEN, b) currents in all conductors after insulation break-down

In the worst situation, it is possible to accept the following conditions:

- only the low-voltage power system is connected and it will be loaded by 50% of lightning current,
- peak value of lightning current 200 kA and shape 10/350 ( values for the I lightning protection level),
- TN-C system (phases L1, L2 L3 and PEN),
- insulation break-down in low-voltage power system caused by voltage differences between L1, L2, L3 and PEN connected to earthing systems.

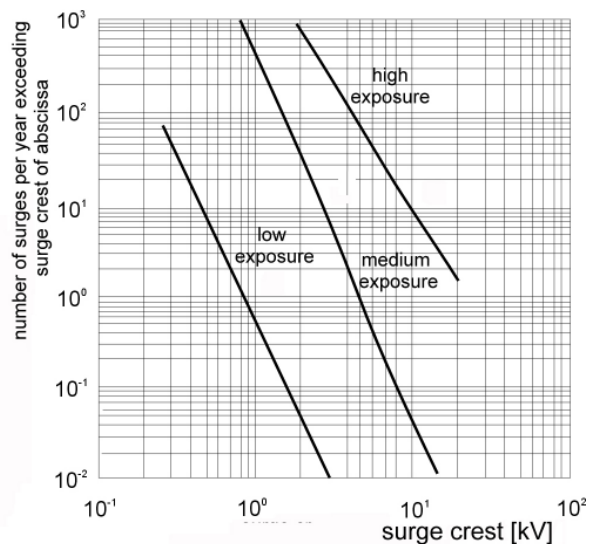
In this case the lightning current of 25 kA will be loading per conductor of low-voltage power system. For typical buildings, smaller value of lightning current (12,5 kA, 10/350) per conductor is recommended.

Considerably often ac electricity meters are exposed to voltage surges from electric power system supplied building. In low-voltage power system inside the structure overvoltages may be classified in the following main categories:

- lightning overvoltages,
- switching overvoltages,
- temporary overvoltages.

Measurements in power systems, laboratory tests and theoretical calculation indicated that these overvoltages have the double-exponential or damped oscillatory waveshapes.

The rate of occurrence of surge voltages varies over wide limits and prediction of this rate for particular installation is always difficult or frequently impossible. Data collected from many surges measurements have led to the plot the curves, which presented the probability of surge voltages exceeding specific values in form of low, medium or high exposure (Fig. 3.).



**Fig. 3.** Rate of surges occurrence versus voltage levels for different exposures [5].

On basis of accessible dates it was possible to accept, that in urban areas overvoltages in range 1000 V- 5000 V occurred about some times per year.

In rural areas the relative probability of occurrence of overvoltages is some times greater than in urban areas.

## 2.2. Surge exposure in medium-voltage power system

Direct lightning discharge to overhead line is the dangerous case for the medium-voltage (MV) systems. The frequency of lightning flashes to overhead line height  $H$  depends on local lightning discharges density, dimensions of line and possible shielding effects of the surrounding.

The number of direct stroke per year can be defined by:

$$N = A \cdot N_g \cdot 10^{-6}$$

where:  $A$  – effective area in  $m^2$ ,

$N_g$  – flashes per km and per year in area with MV line.

In such cases on MV and LV lines flashover will usually occur between line conductors and earth.

The value of overvoltages appears on the inputs of current and voltage measuring transformers dependent on:

- flashover voltages on insulators,
- voltage on inductance and earthing resistance of poles, on which flashover followed.

Considerably smaller values achieved overvoltages induced in overhead lines. In most cases overvoltages have double-exponential or damped oscillatory waveshapes.

The induced lightning overvoltages  $U$  between conductors and earth can be estimated from equation:

$$U = 30 \cdot (H/d) \cdot I \quad [kV]$$

where:  $I$  – lightning current [kA],

$H$  – height of suspension of line above the ground [m],

$d$  – distance among line and place of hitting of lightning [m].

Possibility of assessment the number of induced overvoltages in the function of amplitudes, parameters of line and local flash density is defined by:

$$N_i = 1,9 \cdot 10^{-6} \cdot N_g \cdot H \cdot L \cdot \left[ 3,5 + 2,5 \cdot \log \frac{30 \cdot (1-c)}{U} \right]^{3,75}$$

Where  $N_i$  – number of induced overvoltages,  $N_g$ ,  $H$ ,  $L$  and  $U$  are as presented in previous equations. Coefficient  $c$  defines reducing factor due to earthed neutral or earth conductor ( $c=0$ , in absence of this conductor and  $c=0,7$  or  $0,9$  in dependence from earthing of conductors).

Lightning risk in half-directly and indirectly connection of electricity meters will be presented on examples of measure circuits in power stations, in which control buildings with meters were in considerable distances from the places of instrumental transformers. In these situations, in secondary circuits are necessary signal cables about a few hundred meter lengths. In such arrangements overvoltages transferred from primary sides to secondary windings by inductive, capacitive and impedance (galvanic) couplings.

When the secondary windings were earthing in one point (for example at instrumental transformers), these couplings caused that in the places of measurements (in control buildings) in secondary circuits appeared the overvoltages between conductors and between conductors and earth.

Dates presented in literature and author's measurements show that overvoltages between conductors and earth can achieve values to some kilovolts and in the case of impedance (galvanic) coupling even to 20 kV.

## 3. Overvoltage protection of electricity meters

In case of direct connection of electricity meters to low-voltage power system, protection against lightning current and limitation of overvoltages to adequate level assured SPD type 1 with voltage protection levels below 4 kV. If SPDs are selected accordance IEC 60364-5-534 [10], their voltage protection level shall not exceed 2,5kV.

For the protection against lightning current (Fig.2), arrangement of SPDs shall be installed near the origin of the installation on the supply side of electricity meter (Fig. 4.).

SPDs with discharge spark gaps are recommended [3].

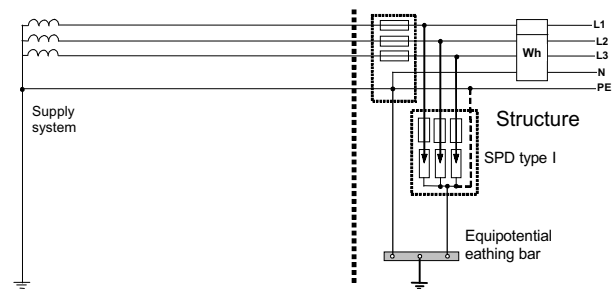


Fig. 4. SPDs on the supply side of electricity meter

Protection against lightning (caused by indirect lightning strokes) and switching overvoltages is provided by installations of SPDs type II (Zinc oxide varistor and spark gap in series connection).

Electricity meter having immunity to surge current of at least 3 kA, 8/20  $\mu s$  shall be used if SPDs are installed on the load side of this meter.

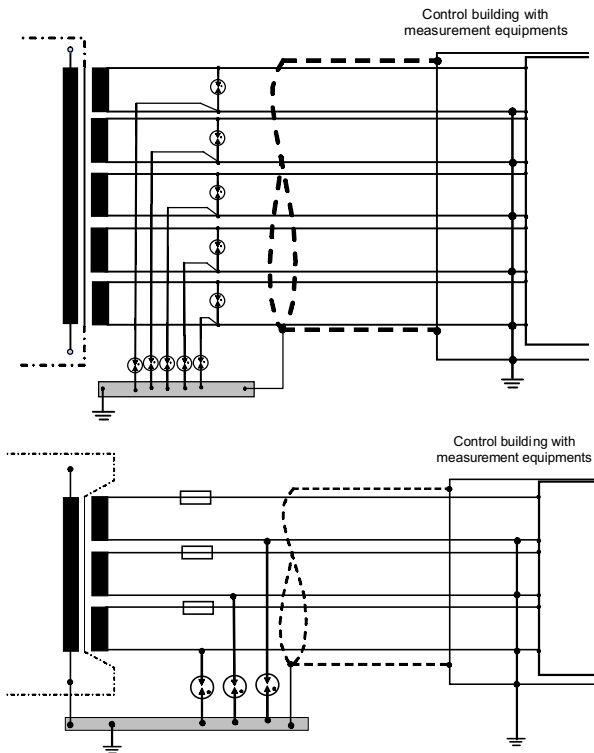
In indirect connection of electricity meters and considerable distance between instrumental transformers and control building potential differences between earthing systems can be dangerous for insulation of measurement circuits.

The solution is the earthing the secondary windings in control building. In this case we avoid in control room the potential of earthing mesh from HV Station. In such arrangement the protection against potential differences between secondary windings and earth at the instrumental transformer is possible to occurred using gas discharge tubes (Fig.5.) with impulse flashover voltage below 6000 V.

When the secondary windings are earthing at instrumental transformer gas discharge tubes should be installed in control building.

## 5. Reference

- [1] Hasse P.: Overvoltage protection for low-voltage systems. The Institution of Electrical Engineers, 2000.
- [2] Draft IEEE Guide on the Surge Environment in Low-Voltage (1000V and less) AC Power Circuits. 1999.
- [3] Vereinigung Deutscher Elektrizitätswerke VDEW – e.V. :Überspannungsschutz-zeinrichtungen der Anforderungs-klasse B. Richtlinie für den Einsatz in Haupt-stromversorgungssystemen.
- [4] Secondary (low-side) surges in distribution transformers. Task Force Report, IEEE Trans. Power Delivery, Vol.7, No. 2, 1992.
- [5] CEI IEC 61643-1: Surge protective devices connected to low-voltage power distribution systems. Part 1: Performance requirements and testing methods.
- [6] IEC 61024-1: Protection of structure against lightning. Part 1: General principle.
- [7] IEC 61024-1-2: Protection of structure against lightning. Part 1: General principle. Section 2-Guide B: Design construction, maintenance and inspection of lightning protection system.
- [8] IEC 61312-1: protection of structure against lightning electromagnetic impulse. Part 1: General principles.
- [9] IEC 62066: General basic information regarding surge overvoltages and surge protection in low-voltage a.c. power systems.
- [10] IEC 60364-5-534: Electrical installations of building, Part 5: Selection and erection of electrical equipment. Section 534: Devices for protection against overvoltages.
- [11] IEC 61000-4-5: Electromagnetic compatibility. Part 4. Testing and measurement techniques – Section 5: Surge immunity test.
- [12] PN-93/E-06504: Liczniki indukcyjne energii czynnej prądu przemiennego klasy 0,5 , 1 i 2 (polish version of IEC 521: Class 0,5, 1 and 2 alternating-current watt-hour meters).
- [13] PN-EN 6004-1: Przekładniki. Przekładniki prądowe (polish version of IEC 60044-1: Instrumental transformers. Part 1. Current transformers).
- [14] Wiater J.M., Sowa A.W. Lightning overvoltages propagation across HV current transformer. EMD 2005, Białystok



**Fig.5.** The protection of measurements circuits against potential differences

## 4. Conclusion

Creation conditions for failure-free work of electricity meters required:

- analyse the lightning and overvoltages risk in places of their installations,
- compare this risk with the surge resistibility level of meters,
- install the protective devices with adequate protection level.

Surge protective devices can't influence onto works of meters.

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